5G
THE NEW MOBILE NETWORK TECHNOLOGY

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SUMMARY

- Mobile Networks History
- Why 4G is not enough ?
- 5G Presentation
- 5G enabling IoT
- 5G use cases – Applications

MOBILE NETWORKS HISTORY

EVOLUTION

	2G GSM	2.7G EDGE	3G WCDMA	3.5 HSPA, HSPA+	4G LTE	4G LTE-Advanced	4,5G LTE-A Pro	5G
3GPP Release	Rel. 97	Rel. 98	Rel. 99	Rel. 5,6,7	Rel. 8,9	Rel. 10,11,12	Rel. 13,14	Rel 15, 16
Use case	Digital voice & messaging Digital fidelity cellular phones	Enhanced 2G Higher data rates	Voice, Data & Video Signals Video Telephony / Internet surfing	Enhanced 3G Higher data rates	Data and Voice over IP Wireless broadband	Enhanced 4G Higher peak rates	4G Evolution towards 5G +IoT and Public safety	eMBB, critical MTC, massive MTC 4th industrial revolution
Channel access	TDMA/FDMA	TDMA/FDMA	WCDMA	WCDMA	OFDMA	OFDMA	OFDMA	Modified OFDMA
Bandwidth	200 kHz	200 kHz	5 MHz	5 MHz	20 MHz	100 MHz	640 MHz	Up to 2 GHz
Service	CS	CS/PS	CS/PS	PS	PS	PS	PS	PS
Architecture	Controller	Controller	Controller	Controller	Distributed	HetNet	Cloud	Cloud, co-existence, slicing
DL speed	40 Kbps	500 Kbps	384 kbps	14-84 Mbps	150-300 Mbps	1 Gbps	3 Gbps	>10 Gbps
Latency	~500 ms	~300 ms	~150ms	~50 ms	~10ms	~10ms	~5ms	<1ms

1982 1G — 1991 — 1997 — 2000 — 2004 — 2007 — 2012 — 2016 — 2020

WHY 4G IS NOT ENOUGH?

WHY 4G IS NOT ENOUGH

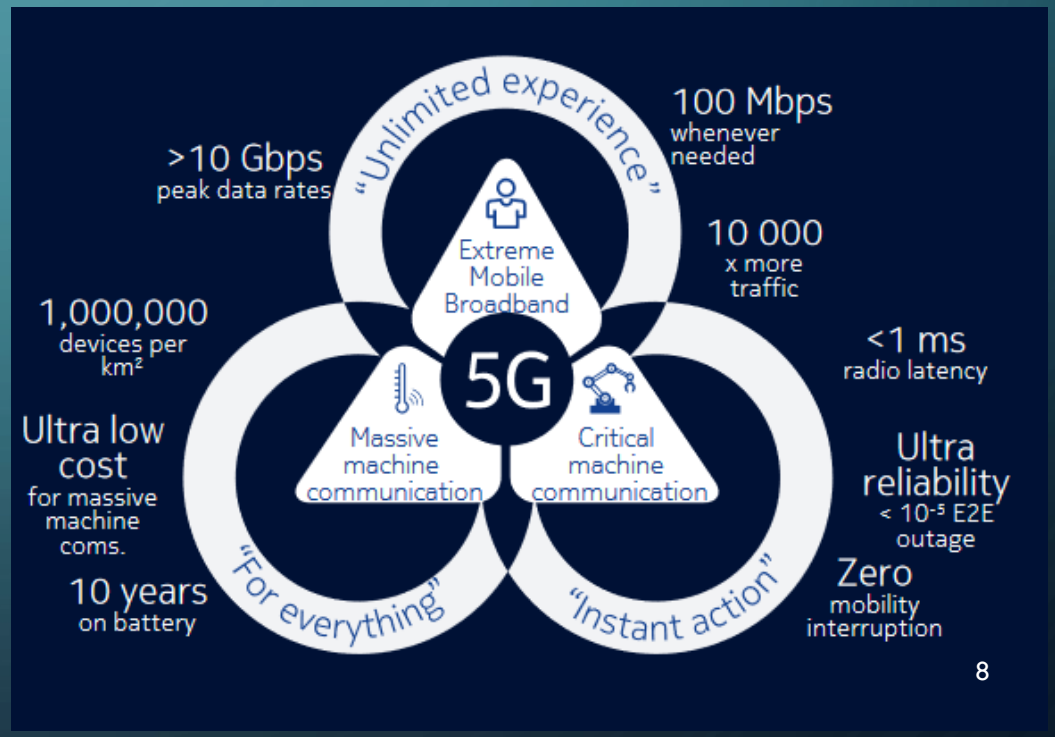
- Number of smartphones users is increasing fastly
- Users need more throughput for :
  - Social networking (Fbook, IG, …)
  - Live streaming
  - Online Video (Netflix, Youtube, ...)
  - Research (google, Yahoo, …)
  - Mobile video Gaming
- IoT growing fast ➔ 50bn things by 2025
- M2M communication need low latency

➔ **4G is not build to support this demand**

5G

WHAT IS 5G

5G is the new generation of radio systems and network architecture delivering extreme broadband, ultra-robust, low latency connectivity, and massive networking for the Internet of Things to enable the programmable world, which will transform our individual lives, economy and society.

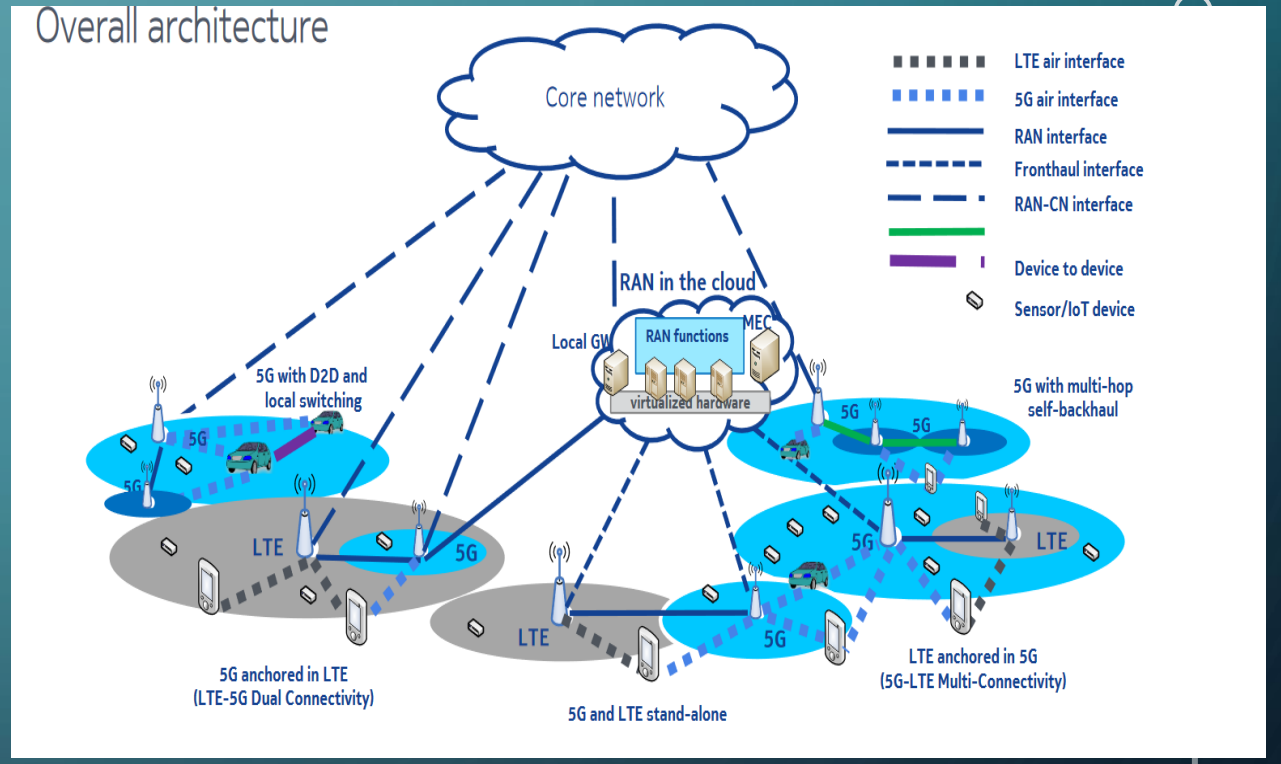


5G advantages

- low latency (<1ms) ➔ M2M communication
- Peak data Rates>10Gbps
- High capacity ➔ 1M devices per km²
- Battery saving for IoT ➔10 years on battery
- Massive Networking

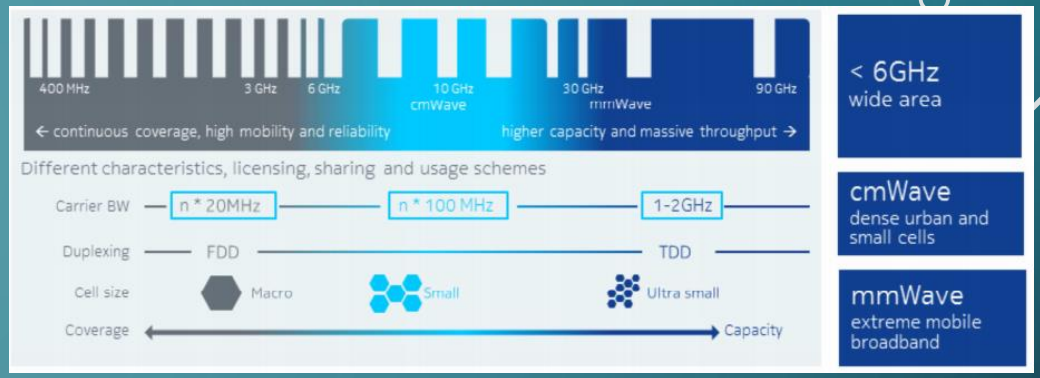
5G E2E ARCHITECTURE

- Almost the same architecture as 4G.
- 2 parts:
  - **RAN**
    - part of the HW RAN in the CLOUD
    - 5G RAC = L3 - located in the cloud. RLC function.
    - 5G RAU = L2 - not virtualized. Scheduler is located in the RAU.
    - RU = L1 - on the radio site; Radio Frequency function
  - **Core Network**
- 5G UE can simultaneously connect in 4G and 5G.
- D2D communication is also possible.



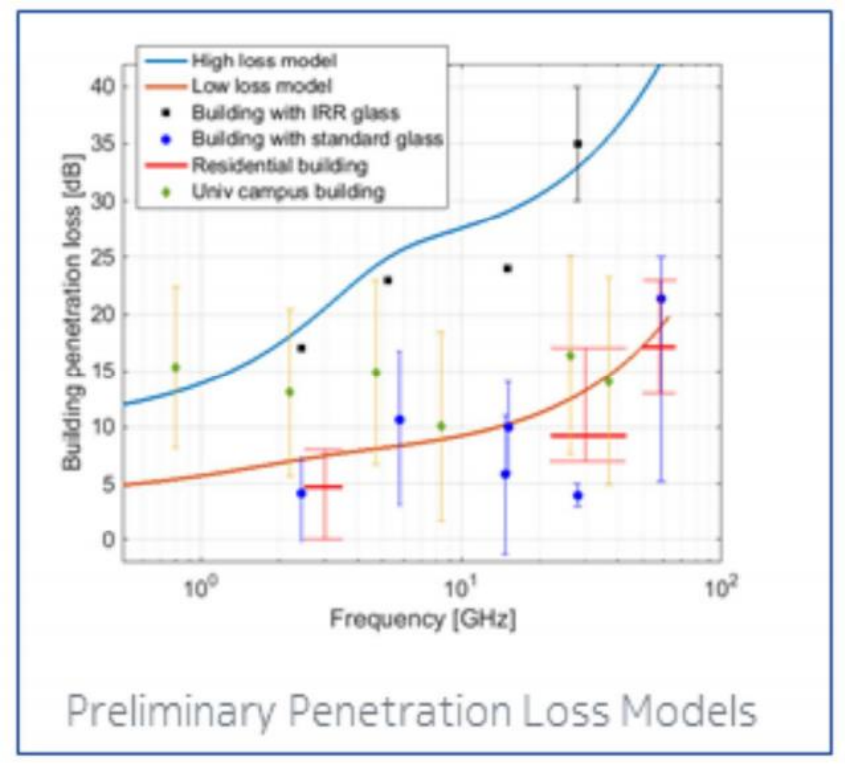
300 000 km/s
300 000 km/s
300 000 km/s

5G NEW RADIO -SPECTRUM



- 5G Radio Access is developed for different spectrum ranges:
  - Below 6 GHz ➔ cmWaves
    - High coverage
    - Capacity boost
    - Antenna size (“regular”)
  - Above 6GHz ➔ mmWaves
    - Medium coverage
    - Ultra high capacity
    - Antenna size smaller

$$\Lambda \text{ (wave length)} = \frac{c\ (light\ celerity = 300.000\ km/s)}{f(frequency)}$$

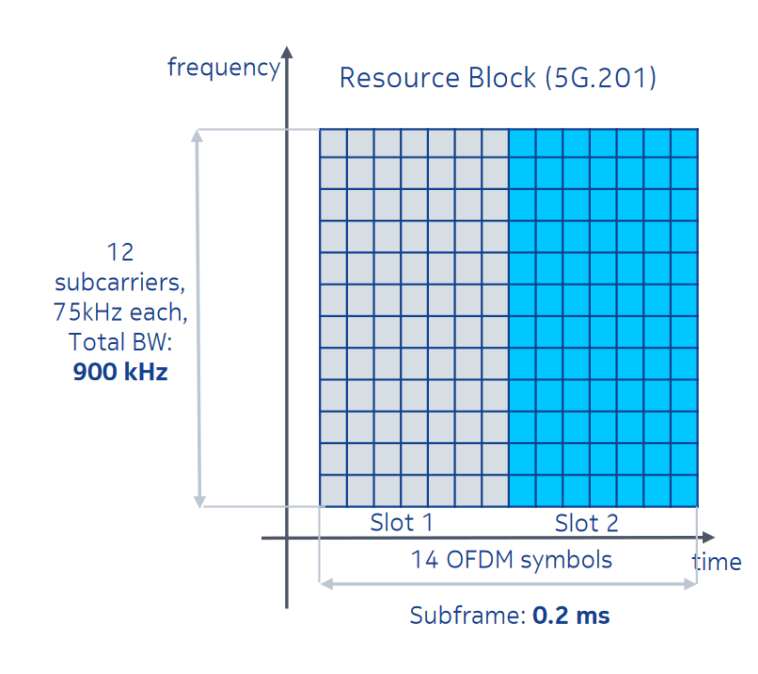


5G NEW RADIO

- Key characteristics of 5G RAT :
  - **Flexibility** in order to allow the support of a multitude of applications with diverse requirements.
  - **Scalability** will render the air interface to be able to scale to a very large number of connections.
  - **Efficiency**, high degrees of efficiency, both in terms of energy and resource utilization
  - **Reliability** for all the use cases and most of the users, the required data will be received in the required time

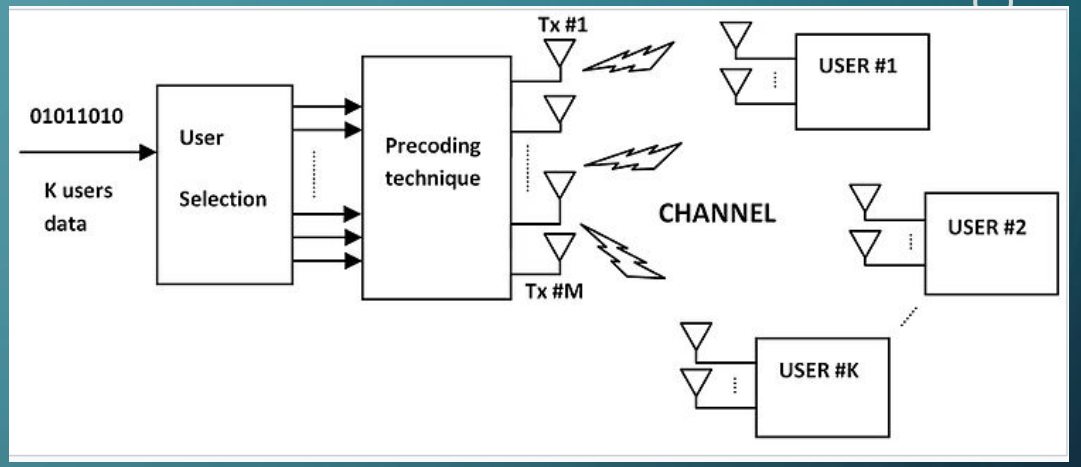
5G NEW RADIO – PHYSICAL LAYER – RESOURCE BLOCKS

- Latency reduction (<1ms) by using smaller TTI (0,2 ms) OFDM symbols.

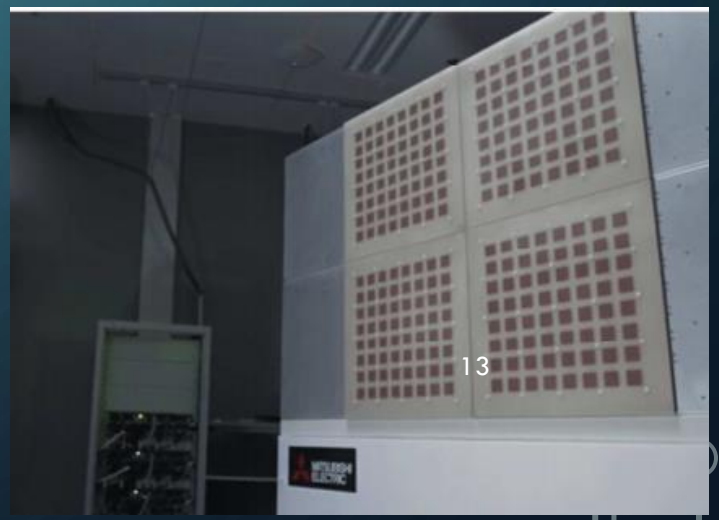


5G numerology is based on LTE		
Parameter	**LTE**	**Verizon 5G = 5G17**
Downlink	OFDM	OFDM
Uplink	DFT-s-OFDM (SC-FDMA)	OFDM
Subcarrier spacing	15 kHz	75 kHz
Sampling rate	30.72 MHz	153.6 MHz
Bandwidth	1.4, 3, 5, 10, 15, 20 MHz	100 MHz
OFDM symbol duration, no CP	66.67 µs	13.33 µs
Subframe length (TTI)	1 ms	0.2 ms
Frame length	10 ms	10 ms
#Subframes (#slots)	10 (20)	10 (100)
CP type	Normal & extended	Normal only
Multiplexing	FDD / TDD	Dynamic TDD
Max PRBs	6, 15, 25, 50, 75, 100	100
DL/UL data coding	Turbo code	LDPC code

5G NEW RADIO – MASSIVE MIMO



- Massive MIMO : Multiple Input Multiple Output
- Becoming mature and use in LTE and Wi-Fi
- Based on antenna arrays with a few hundred antennas simultaneously serving many tens of terminals at the same time-frequency resource.
- More antennas the transmitter/receiver, better data rate, link reliability, reduced latency
- The price to pay: the hardware complexity & energy consumption



5G NEW RADIO – PHYSICAL LAYER – BEAMFORMING

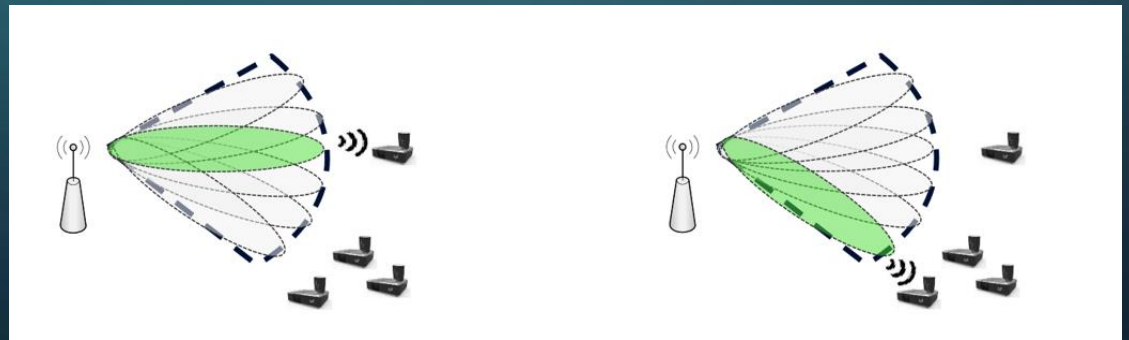
5G NEW RADIO – PHYSICAL LAYER – BEAMFORMING

Advantages:

- Boosting the power of beams in the desired direction to serve the farthest subscribers in a best way
- Increase supporting (number of subscribers)
- RF signal overcome noisy and attenuating channel environment.
- Immunity against fading and interference
- Increase coverage capacity of the cell tower or base station.

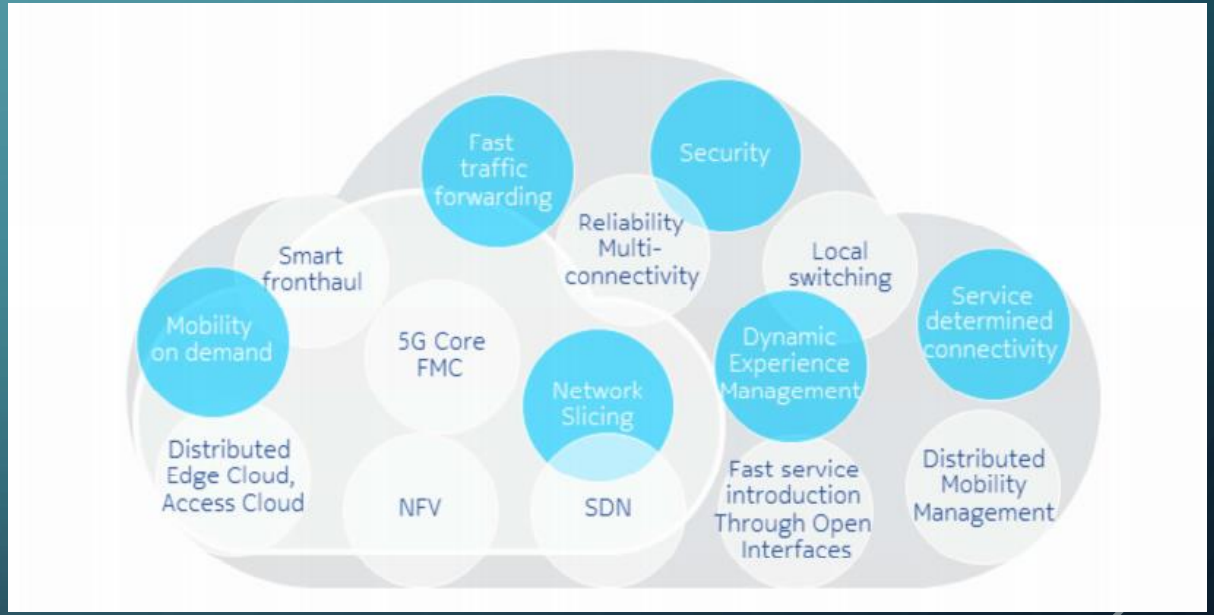
Disadvantages:

- hardware complexity higher.
- system based on advanced high processing DSP chips ➔ more power consumption required.
- cost of beamforming system gets higher



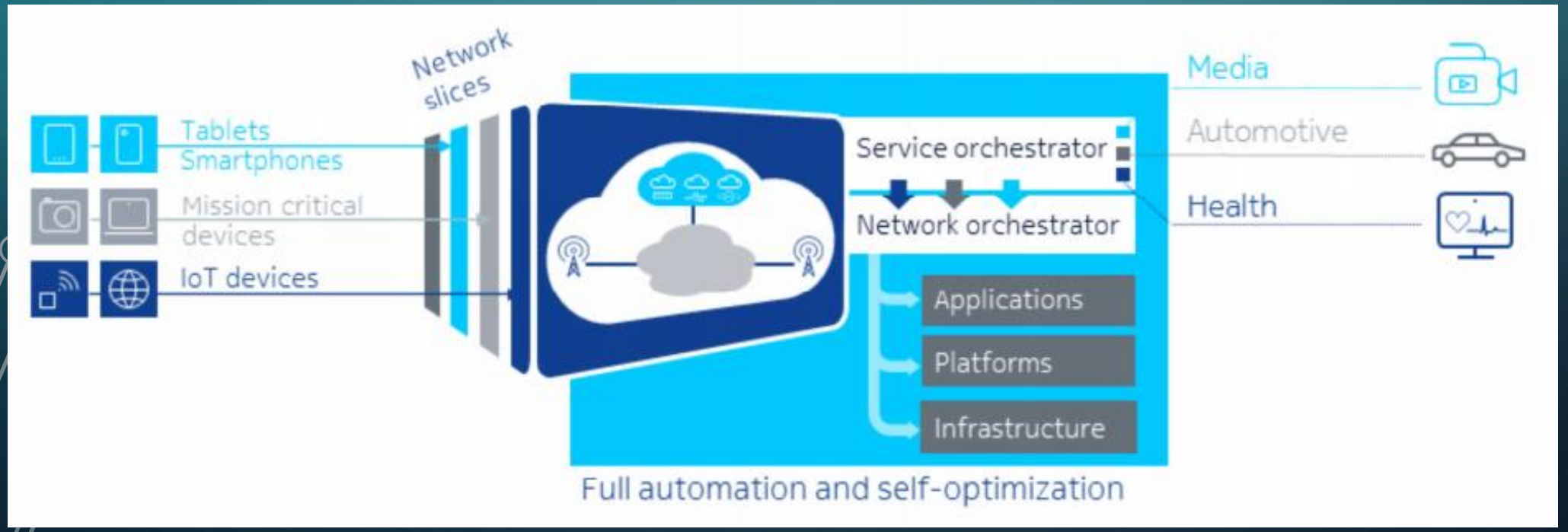
5G CORE

- 5G implement new network architecture based:
  - Network Function Virtualization (NFV)
  - Software Defined Networking (SDN) technologies.
- The key building blocks for 5G core :
  - Network Slicing
  - Dynamic Experience Management (DEM)
  - Service-determined connectivity
  - Fast traffic forwarding
  - Mobility on demand
  - Security



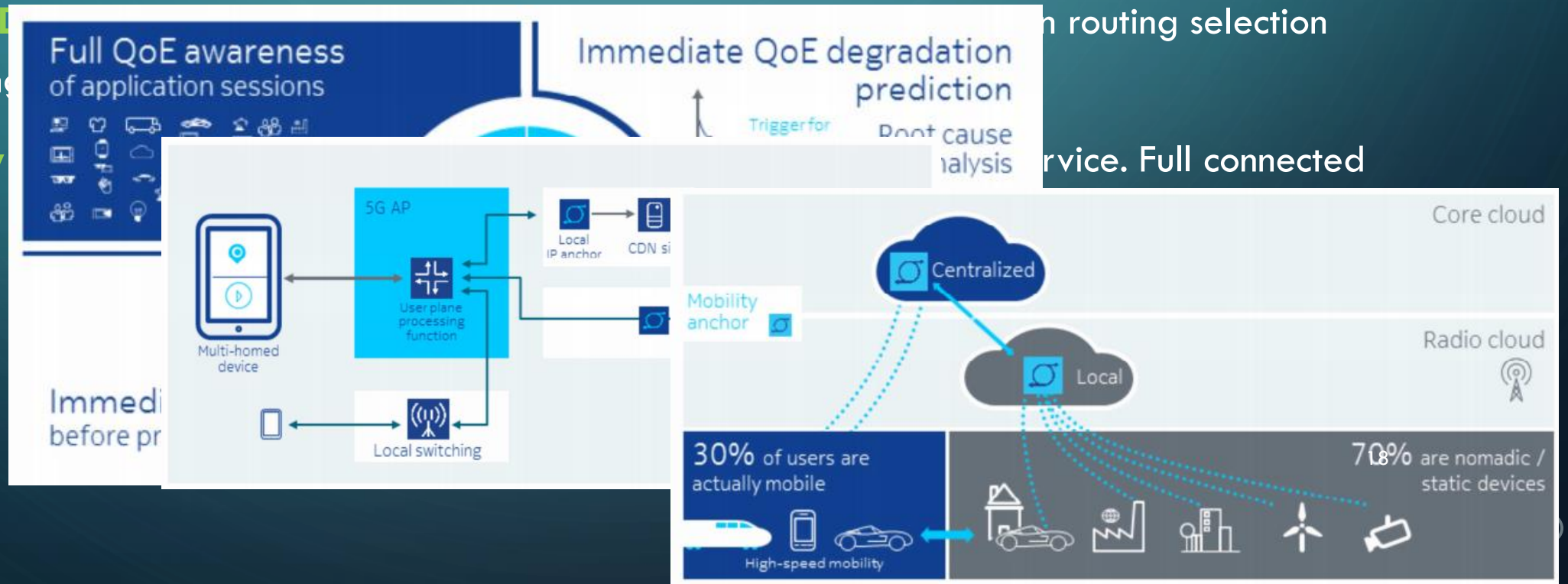
5G CORE

Network Slicing: virtual independent sub networks (flot of functions for each use case) assembled in the 5G network.

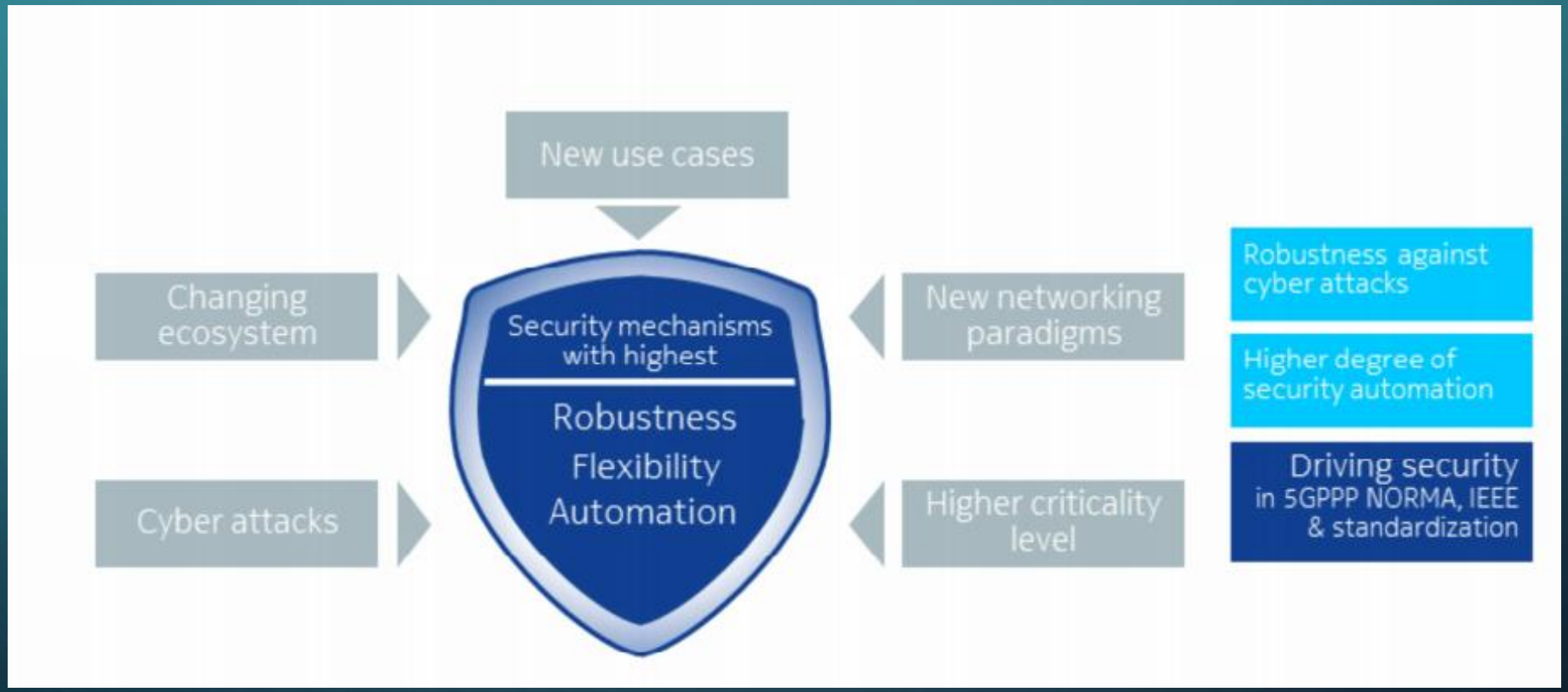


5G CORE

- **Dynamic Experience Management**: automated optimisation of QoE for each application session. By detected '**Sense**' the problem→**Analyze**→**Decide**→ **Act.**
- **Service D** …n routing selection accordin
- **Mobility** …rvice. Full connected and idle



5G CORE - SECURITY



5G CORE - SECURITY

Overview of the security architecture

The gNB can be split in DU and CU; and CU can reside in a physically secure location. This was important for reaching agreement on UP security termination in the gNB.

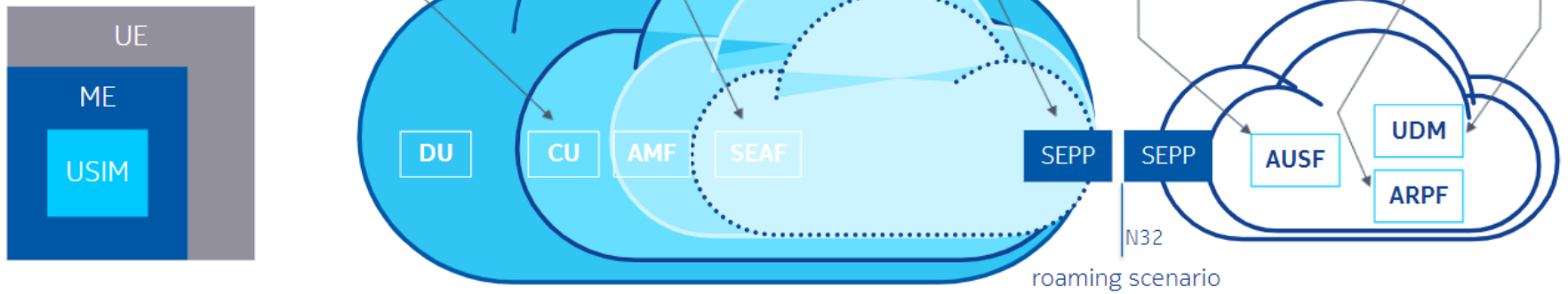
AMF is collocated with the **SEAF** (SEcurity Anchor Function) that holds the root key (anchor key
The SEAF shall support primary authentication using SUCI.

The **SEPP** (Security Edge Protection Proxy) implements application layer security for all the service layer information exchanged between two NFs across two different PLMNs

UDM uses the subscription data stored in UDR and implements the application logic to perform various functionalities such as **authentication credential generation**, user identification, service and session continuity etc

The AUSF (Authentication server function)shall handle authentication requests for both, 3GPP access and non-3GPP access

ARPF (Authentication credential Repository and Processing Function) keeps the authentication credentials



roaming scenario

5G CORE - SECURITY

Ciphering & integrity protection

- User encryption mandatory to support (128 & 256-bit encryption keys)
- UP integrity mandatory to support and optional to use by 5G UEs and 5G networks

Terminating points	Ciphering	Integrity Protection
NAS Signalling	AMF	AMF
RRC Signalling	gNB	gNB
User Plane Data	gNB	gNB

Authentication Support:

- Two authentication methods, 5G AKA (enhancing LTE's EPS AKA) and EAP-AKA'
  - AKA: Authentication and Key Agreement, EAP: Extensible Authentication Protocol
- Both applicable for 3GPP as well as non-3GPP access

5G IOT

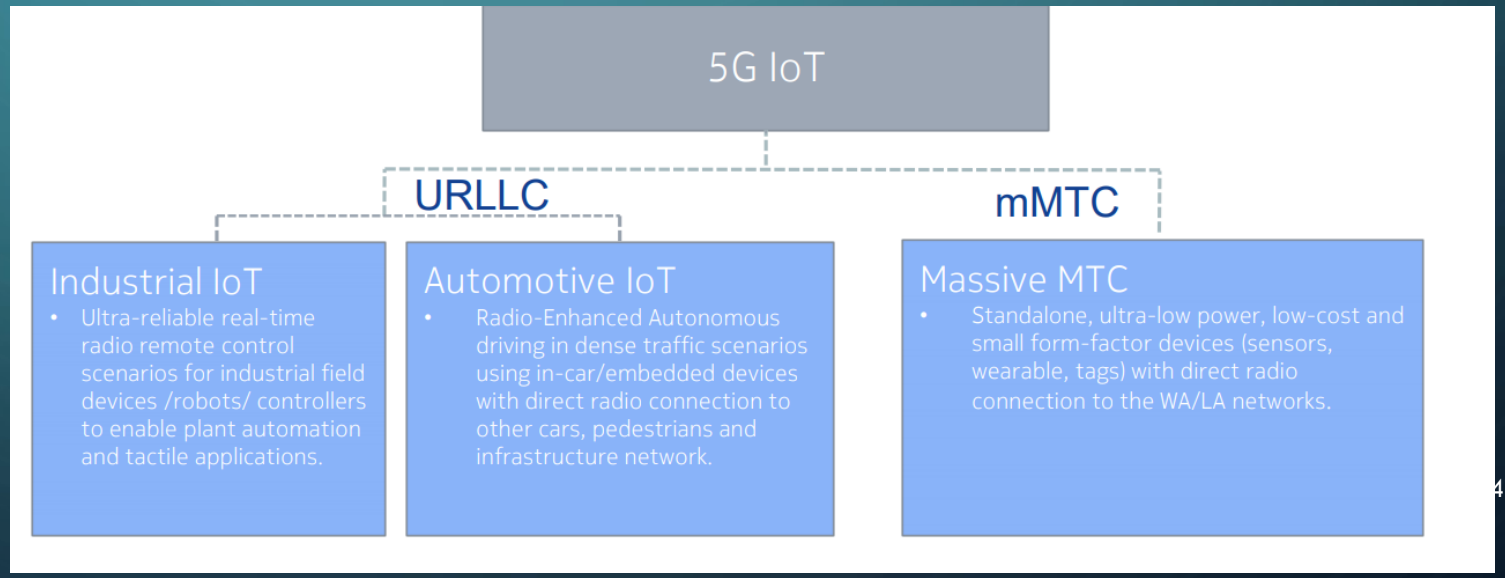
5G IOT COMPARE TO OTHER IOT TECHNO

IoT Technology Space

	SIGFOX	LoRa	Short-range	NB-IoT Rel. 13	LTE-M Rel. 13	EC-GSM Rel. 13	5G (targets)
Range MCL	<12km 160 dB	< 10km 157 dB	10cm to 200m	<35km 164 dB	< 100km 156 dB	< 35km 164 dB	<12km 160 dB
Spectrum Bandwidth	Unlicensed 900MHz 100Hz	Unlicensed 900MHz <500kHz	Unlicensed 2.4 GHz	Licensed IMT 200 kHz shared	Licensed IMT 1.4 MHz shared	Licensed 8-900MHz shared	Licensed IMT Shared
Data rate	<100 bps	<10 kbps	<100 Mbps	<62 kbps UL <26 kbps DL	<1 Mbps	<200kbps	<100 Mbps
Use case	Smart Grid/City/ Monitoring	Smart Grid / City/ Monitoring	Smart home/factory	Smart Grid/City/ Monitoring	Smart Grid / City / Monitor./ vehic.	Smart Grid / City / Monitor./ vehic.	Smart Grid / City / Monitor./ vehic.
Module cost	4.00$ (2015) 2.64$ (2020)	4.00$ (2015) 2.64$ (2020)	Not available	4$ (2016) 2-3$ (2020)	5.00$ (2016) 3.30$ (2020)	4.5$ (2016) 2.97$ (2020)	<$2
Network cost, US example* (cost drivers)	$10/year/km^2 >$80M/year (HW+SW+Service)	$10/year/km^2 >$80M/year (HW+SW+Service)	Not available	$1/year/km^2 <$7M/year (SW upgrade)	$1/year/km^2 <$7M/year (SW upgrade)	$1/year/km^2 <$7M/year (SW upgrade)	Included in 5G deployment

5G IOT

- 5G IoT can be separed in 2 groups :
  - URLLC: Ultra Reliable Low Latency Connectivy
  - mMTC: massive Machine Type Communication



URLLC- INDUSTRY AUTOMATION

Application: Ultra-reliable real-time radio remote control scenarios between industry field devices/robots/controllers to enable plant automation and tactile applications. Complement other non-radio based solutions: sensors, local computing, optical communications etc.

Reliability-Delay trade-off: ultra-low latency (<1ms); ultra-high reliability (>99.99999%) for certain radio links only

Spectrum use: WA @<6GHz dedicated, licensed, flexible bandwidth (1-10MHz); D2D @cmWave, licensed, flexible bandwidth (10-100MHz)

Number of devices per sqkm: up to 30.000

Traffic type: periodic and event-triggered, small/medium data packets

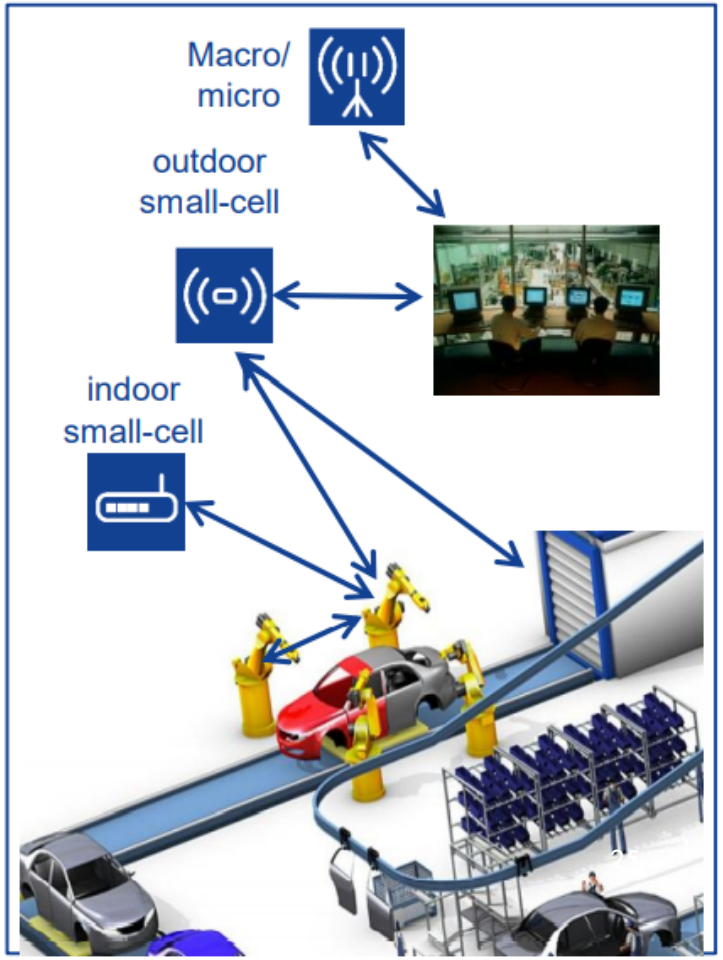
Description

Data rates DL/UL: <5Mbps (scalable)
Power consumption: Not important
Device cost: Medium/High
Mobility & handover: low to medium, limited
Maximum speed: 40km/h
Multi-layer/cell connectivity: Full (always)
D2D support: Yes

Requirements

Access mode: flexible TDD or FDD, local routing capability @ access node
Multi-layer/cell connectivity: 5G macro/small- cell, D2D / sidelink
Multi-antenna techniques: MIMO, CoMP
Multi-band deployment: <6GHz & cmWave
Deployment: HetNet, dedicated cells, mesh/star network topologies

Enabling technologies



IOT – FULLY AUTONOMOUS DRIVING EXPERIENCE

tive on nce	Remote controlled driving
ast	V2I unicast
ps	15Mbps
s	<20ms
9%	>99,999%
nd l	large
ds	Hours
	1
n	
tive Vision)	

5G SIM

5G IoT devices use eSIM or nanoSIM

- nano-SIMs : 40% smaller than micro.
- The eSIM : new type of SIM technology, eliminates the need for a physical card.

Nano-Sim advantages

- **Easy to find**
- **Easy to transfer to a new phone**
- **Easy to get a new number**

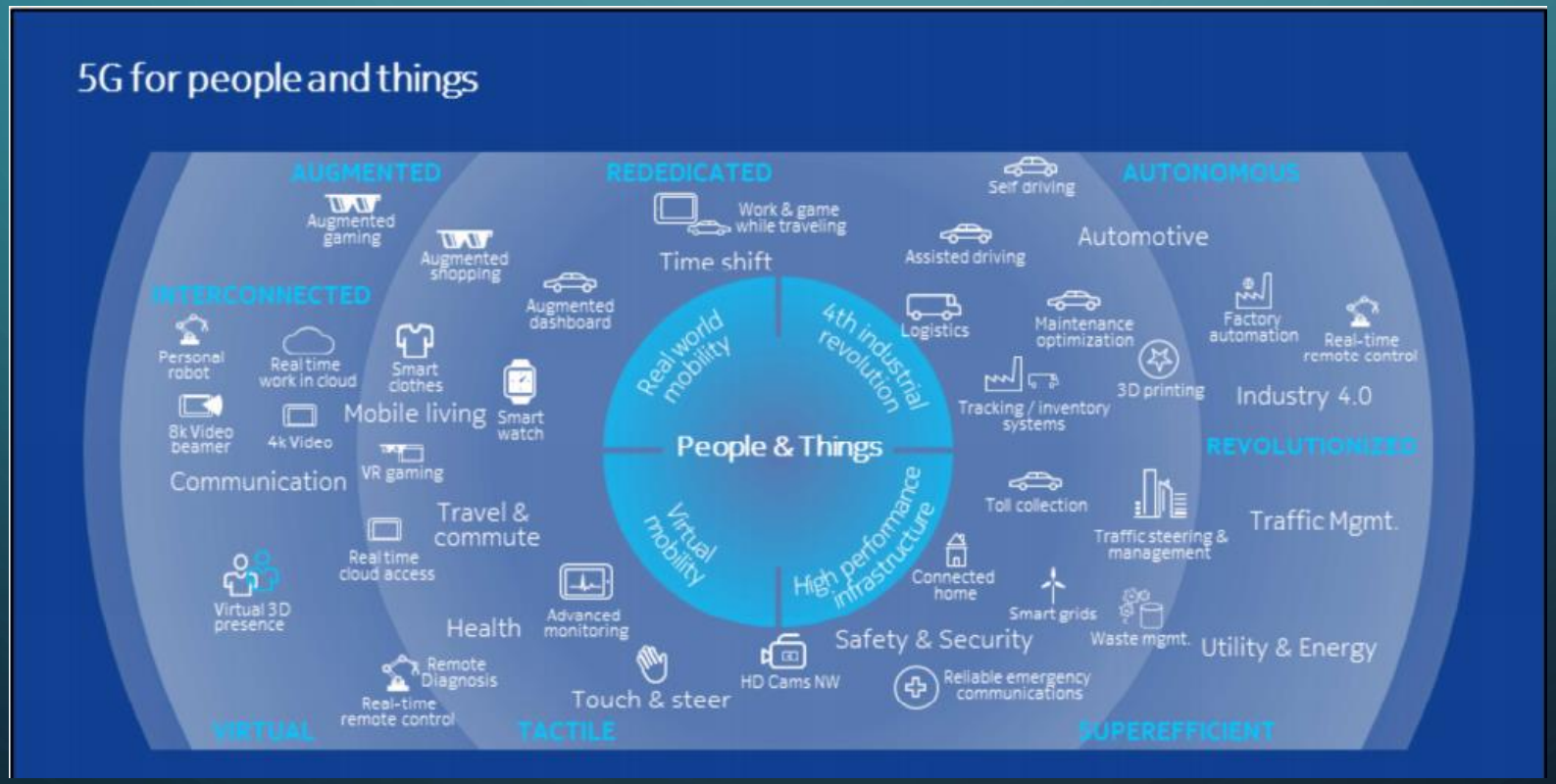
eSim advantages

- **Multiple eSIMs:** up to 15 or 20 eSIMs stored on your phone.
- **To keep your numberRegional plans.**
- **Something you won't lose**

5G USE CASES – APPLICATIONS

5G USE CASES

- 5G will be about people and things.



5G USE CASES -AR

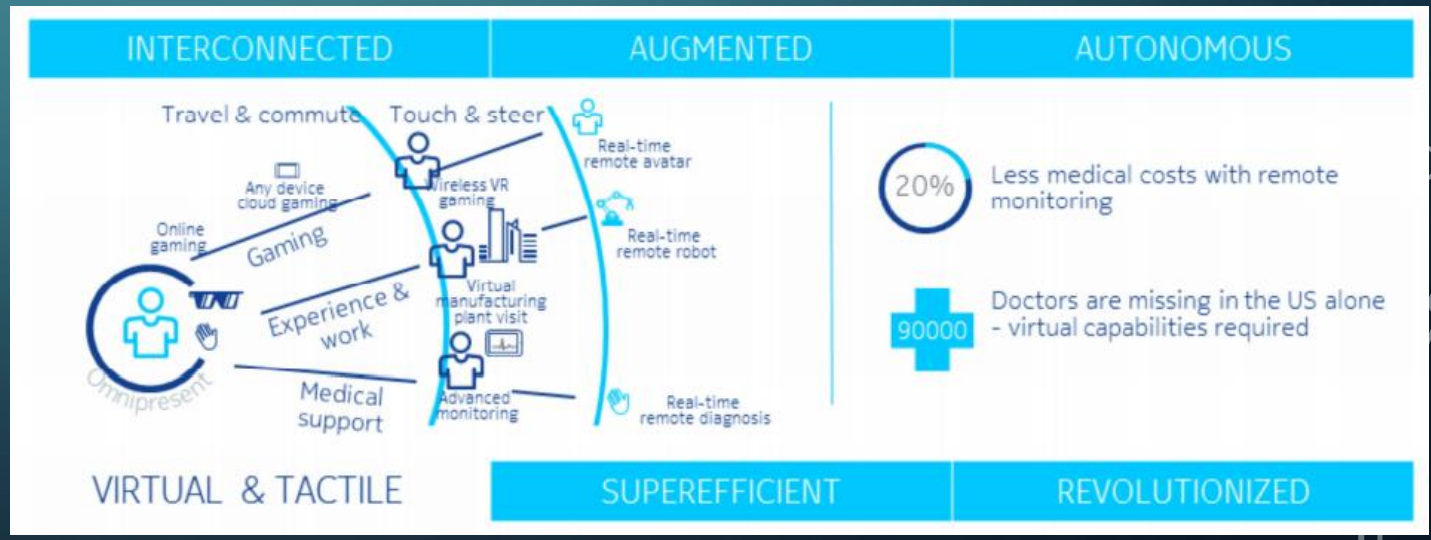
Augmented Reality (AR) enhances a real-world view with graphics. Real-time information is displayed based on the user's location and/or vision.

- Augmented Reality used for:
  - Military
  - Industrial
  - Medical applications
  - Commercial and entertainment areas

5G USE CASES -VR

Virtual Reality (VR) creates a totally new user experience with the user being in a fully immersive environment.

- Virtual Reality used for
  - Gaming
  - Entertainment
  - Students



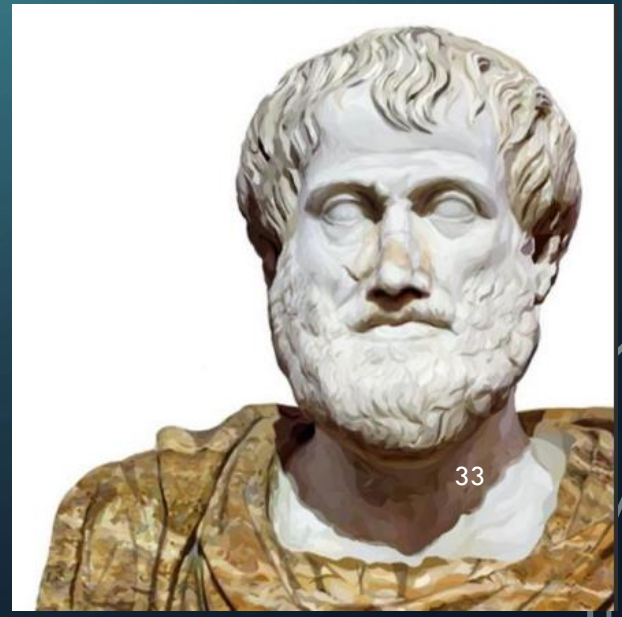
5G USE CASES

- Smart City
- Fully automated and flexible production system
- Wearable devices : smart watches, fitness trackers, health devices, …
- Remote Robotics surgery
- Autonomous vehicules

CONCLUSION

5G : one of the last steps of the long-standing dream (facilitate human's life)

"Suppose every instrument could by command or anticipation of need, execute its function on its own; then craftsmen would have no need of hand-work and masters have no need of slaves." Aristotle (384 - 322 BC)



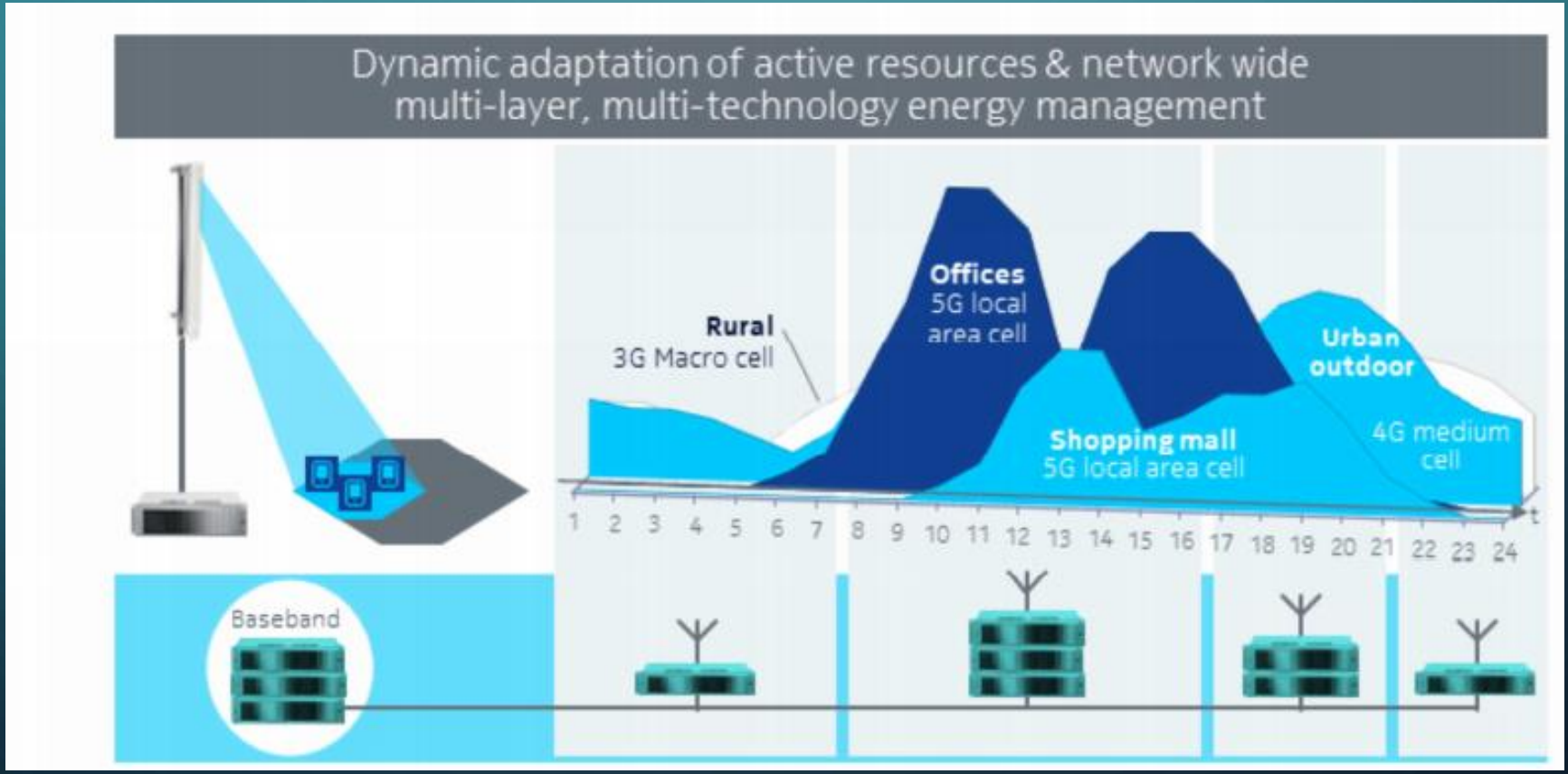
Q&A

ENERGY EFFICIENCY

- In 2013, worldwide telecoms Networks consumed around 83 GW ➔ 12 new York cities consumption. It's increasing since.
- Energy efficiency of the networks is a key factor to minimize the Total cost of Ownership (TCO), along with the environmental footprint of networks. As such, it is a fundamental design principle of 5G.

ENERGY EFFICIENCY – NETWORK SIDE

Adaption of energy consuming resources to the actual demand for capacity.



ENERGY EFFICIENCY – UE SIDE

The target for UE battery life should be 10 years